

## CLAIMS

- 1     1.     Microwave apparatus for measuring blood flow rate in a patient's blood vessel,  
2     said apparatus comprising,  
3             an intravascular catheter having proximal and distal ends and containing an inner  
4     coaxial cable forming a first antenna and an outer cable coaxial with the inner cable and  
5     forming a second antenna, said first antenna extending axially beyond the second antenna  
6     a selected distance;  
7             an extracorporeal control unit including a microwave transmitter, a microwave  
8     receiver and a processor controlling the transmitter and receiver, and  
9             a diplexer connected between said first and second antennas and the control unit  
10    for coupling signals from the transmitter to one of the antennas but not to the receiver and  
11    for coupling signals from the other of the antennas to the receiver but not to the transmit-  
12    ter.
- 1     2.     The apparatus defined in claim 1 wherein  
2             the transmitter transmits signals of a first frequency, and  
3             the receiver is designed to receive signals of a second frequency different from  
4     the first frequency.
- 1     3.     The apparatus defined in claim 1 wherein the diplexer is contained in a proximal  
2     end of the catheter.

1     4.     The apparatus defined in claim 1 wherein  
2             the transmitter transmits signal pulses to said one of the antennas and, each time,  
3     sends a transmit signal to the processor;  
4             the receiver sends a detect signal to the processor each time it detects a signal  
5     from said other of the antennas, and  
6             said processor includes means for determining the elapsed time between the re-  
7     ception of a transmit signal and a subsequent detect signal and means for dividing that  
8     time into the axial distance between said first and second antennas to compute said flow  
9     rate.

1     5.     The apparatus defined in claim 4 wherein the control unit also includes a display  
2     device controlled by the processor for displaying the flow rate.

1     6.     The apparatus defined in claim 1 wherein the inner coaxial cable is slidable rela-  
2     tive to the outer coaxial cable so as to allow adjustment of said selected distance.

1     7.     The apparatus defined in claim 1 wherein the diplexer is mounted to a proximal  
2     end of the catheter and includes  
3             radially spaced-apart inner and outer tubular conductors surrounding a segment of  
4     said inner coaxial cable and connected electrically to said outer coaxial cable;  
5             a tubular side branch extending from said outer conductor;  
6             a branch conductor extending from said inner conductor through said side branch  
7     to form a port;

8           a short circuit between said inner and outer conductors at a distance from said  
9   branch conductor to form a quarter wavelength stub at the frequency of the signal carried  
10 by the outer antenna.

1   8.     The apparatus defined in claim 7 wherein the inner coaxial cable is slidable rela-  
2   tive to the outer coaxial cable and inner conductor so as to allow adjustment of said se-  
3   lected distance.

1   9.     Microwave apparatus for measuring the blood flow in a patient's blood vessel,  
2   said apparatus comprising  
3         an intravascular catheter having proximal and distal ends and containing an inner  
4   coaxial cable forming a first antenna and an outer coaxial cable forming a second an-  
5   tenna, said first antenna extending axially beyond the second antenna a selected distance,  
6   and  
7         a diplexer at the proximal end of the catheter, said diplexer having radially  
8   spaced-apart inner and outer conductors, said inner conductor snugly receiving the inner  
9   coaxial cable and the inner and outer conductors being connected electrically to the outer  
10  coaxial cable, said outer conductor having a tubular branch oriented substantially 90°  
11  relative to the inner conductor and said inner conductor having a connection extending  
12  through said branch and being spaced from corresponding shorted ends of the inner and  
13  outer conductors to form a quarter wave stub at the frequency of the signal carried by the  
14  second antenna.

1    10.    The apparatus defined in claim 9 wherein the inner coaxial cable is slidable  
2    lengthwise relative to the outer coaxial cable and an inner conductor so as to allow ad-  
3    justment of said selected distance.

1    11.    The apparatus defined in claim 9 wherein the inner coaxial cable has an open-  
2    ended tubular inner conductor which extends the length of the catheter.

1    12.    Microwave apparatus for measuring blood flow in a patient's blood vessel, said  
2    apparatus comprising  
3            an intravascular catheter having proximal and distal ends;  
4            a diplexer at the proximal end of the catheter, said diplexer including  
5                    a radially outer tubular conductor having a tubular side branch, and  
6                    a radially inner tubular conductor spaced from the outer conductor and  
7    having a connection extending through the side branch of the outer conductor to the out-  
8    side to form a first port, said inner and outer conductors having proximal ends which are  
9    short circuited to form a quarter wave stub between said proximal ends and the side con-  
10    nection of the inner conductor;  
11            a first antenna at the distal end of the catheter, said first antenna including radially  
12    inner and outer electrically insulated tubular conductors connected electrically to the re-  
13    spective inner and outer conductors of the diplexer, and  
14            a second antenna at the distal end of the catheter spaced axially beyond the first  
15    antenna, said second antenna including a coaxial cable having an inner conductor and

16 which extends through the inner conductor of the diplexer to the outside to form a second  
17 port.

1 13. The apparatus defined in claim 12 wherein the coaxial cable is slidable within the  
2 inner conductors of the first antenna and diplexer to adjust the axial distance between the  
3 first and second antennas.

1 14. The apparatus defined in claim 12 wherein the inner conductor of the coaxial ca-  
2 ble of the second antenna is an open-ended tube adapted to slidably receive a guide wire.

1 15. A method of measuring intravascular blood flow in a blood vessel, said method  
2 comprising the steps of  
3 introducing into the blood stream a catheter having first and second microwave  
4 antennas spaced apart axially a selected distance;  
5 transmitting a signal pulse to the first antenna which suffices to heat blood present  
6 at the first antenna to produce a thermal anomaly in blood flowing in said blood vessel;  
7 detecting said anomaly when it travels to the second antenna to produce a detec-  
8 tion signal;  
9 determining the time interval between said pulse and said detection signal, and  
10 dividing said time interval into said selected distance to compute the flow rate of  
11 blood in said blood vessel.

1 16. The method defined in claim 15 including the step of displaying the computed  
2 flow rate.

1 17. The method defined in claim 15 including the step of forming the first and second  
2 antennas at the ends of radially inner and outer electrically insulated coaxial cables, the  
3 inner cable extending axially beyond the outer cable.

- 1 18. The method defined in claim 17 including the step of connecting the cables to a  
2 diplexer to separate inner and outer cables and to decouple the signals thereon.